The Development of Operations Analysis and Supportive Information System (OASIS) for Archived Traffic Data Management on the Freeway

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ABSTRACT

ITS(Intelligent Transport Systems) is a system for solving traffic problems by maximizing the reliability and efficiency of the traffic control system via the cooperative technology among the fields of traffic, information technology, communication, and electronics. ITS is a system for monitoring the real-time traffic and is implemented by establishing various vehicle detection mechanisms to obtain real-time traffic information. Currently the FTMS(Freeway Transportation Management System) of Korea Expressway Corporation is in use and provide real-time traffic information. This system enables the distribution of traffic and enhances the efficiency of the freeway operations. However, this system cannot provide any analysis capabilities based on a long-term period and therefore are not suitable for supporting decision making processes for traffic planning or operating strategies.

In this paper, we provide a survey on archived data management system and, propose system architecture, web-based user interfaces for effectively maintaining historical traffic data on freeway.

1. INTRODUCTION

Korea Express Corporation has installed and operates about 3,000 Vehicle Detection Systems (hereinafter referred to as VDS or VDSs) and about 1,000 CCTV cameras (hereinafter referred to as CCTV or CCTVs) on 3,000 km of expressways as of 2006 for the advanced operation and management of expressways. Among them, the general data collected from the VDSs reaches up to about 7 GB a day with about 3 million cases of daily traffic data (such as the time between tollgates and the traffic volume) from about 700 VDSs on national bypass roads (665 km) and Toll Collection Systems (hereinafter referred to as TCS or TCSs). That is, the data equivalent to 40 years of newspapers is collected every day.

This data is mostly used to provide real-time traffic information and to promptly identify the traffic situation but the saving and use of the past data, i.e. historical data, has been very poor. We can get incalculable information and indications using the previous data. Notably, as the range of

utilization, such as the improvement of the traffic management function, the development of new technologies, and the support for decision-making for traffic policies, is very wide and long-term data analysis is possible as well as short-term data analysis, the policies related to expressways may efficiently be established[1, 2].

As the representative case, the USA came to keenly recognize the importance of the data through a series of large events such as the 9.11 Terror Attack in 2001, the wood fire in California in 2003, and the large power failure event in the northeastern area. They have had a deep interest in the use of historical traffic data for prompt decision making regarding passenger traffic and logistics areas when serious situations occur and have actively conducted various kinds of studies on the accumulation and the use of historical traffic data in recent years. In the case of our country, interest in the various offline analyses and studies on long-term historical traffic data, as well as the operation and management of real-time data, has recently been an increasing trend. Therefore, Seoul has constructed the Traffic Operation and Planning Information System (TOPIS) to support the data services and decision-making processes for traffic policies in connection with, and for the integration of, the information from the individual centers and the Ministry of Construction and Transportation and related institutes. They actively collect historical traffic data and conduct studies into the use of such data.

The Korea Expressway Corporation (Highway & Transportation Technology Institute) constructed the basic facilities to accumulate and use the historical traffic data from expressways in November 2006 and intends to complete the development of the Operations Analysis and Supportive Information System (hereinafter referred to as OASIS) based on such facilities by the end of 2009. OASIS includes meteorological information and CCTV traffic video information as well as VDS, TCS data, various kinds of incidental data, and traffic operation and management data and may save, manage, and operate the DB for the prompt utilization of long-term historical traffic data. Based on this system, it is possible to maximize the credibility level and utilization level of the data, as well as the development of new traffic technologies, through various experiments, to support prompt decision making for expressway traffic policies, and to provide useful basic data that is needed in the communication and the establishment of safety measures. The name, OASIS, means the system that provides useful information for efficient traffic management and road users, as well as the support of decision making for the traffic policies, based on various traffic operation analyses. That is, it may be considered to be the oasis of traffic information and means a system that clearly solves traffic problems using highly credible and useful data, just like an oasis in the desert.

In this thesis, the configuration and elements of OASIS that are the basic facilities for analyzing and studying the historical expressway data are described. In addition, the system for the historical expressway data which is run in the basic facilities described in this thesis is described and the various analyses and uses of the historical data are discussed.

As the accumulated large-capacity rough and processed data must be provided so that it can be searched through and provided to users based on the web, the design and implementation of web-based data management programs is described, the measures to implement the saving of large-

capacity rough data and processed data are suggested, and the methods and user interfaces to search through such large-capacity traffic data are described in this thesis.

2. THE ARCHIVED DATA MANAGEMENT SYSTEM

(1) ADMS vs. ADUS

The ADMS (Archived Data Management System) is the system that has been constructed to support the analyses based on the long-term and large-capacity data collected from the traffic operation systems. The ADUS (Archived Data User Service) is the component that provides users with the services referring to the data from the ADMS, as an element of the ADMS. When traffic studies and analyses are compared with cooking, the various kinds of traffic data used in the studies and analyses are equivalent to the ingredients for cooking. Like cooks who cook foods with unique methods using various cooking materials, traffic researchers can perform analyses using various analysis methods. The extreme purpose of the construction of the ADMS is to accumulate and provide long-term historical traffic data for the researchers and, based on this data, it is possible to provide highly credible and high-grade data by variously verified or studied processing methods. That is, as strictly selected, various, and high-grade cooking materials are provided to the cooks, the time wasted because cooking is impossible due to lack of ingredients and the time taken to cook or process the ingredients may be saved. As the collected data is managed independently from the operation system, the researchers may perform no-risk analyses with no influence on real-time operation systems.

Figure 1 shows the relation between the ADMS and ADUS in the ITS architecture of the USA. As shown in the figure, the ADUS plays the role of a relay between the ADMS and its users; it requests saved data or analyzed data and shows the results to the users. Such historical data may be collected from various sources rather than a specific organization and the manager in charge of the management of the saved data can perform the command to save and manage the data, can collect and analyze the management data, and can reflect the results to a saved data management system.

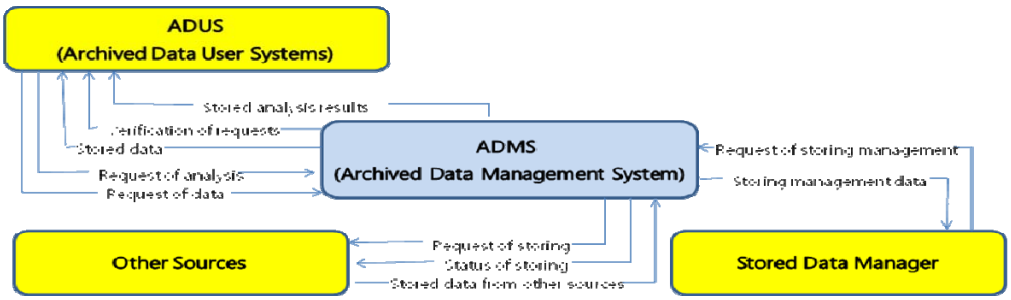

Figure 1. The ADMS and ADUS of the ITS architecture of the USA

(2) Consideration in Construction of the ADMS

The traffic data for the construction of the ADMS is different from the real-time data in many aspects. As shown in Table 1, real-time data and historical data are different; historical data is

significantly larger and more complicated in terms of the volume and complication level of the saved data compared with real-time data and the configuration of the system should be designed in consideration of the volume of the data and the complication levels of analyses rather than the number of unit transactions to be considered in the real-time system.

Table 1. Comparison of the real-time and historical data of traffic data

Classification	Real-Time Data	Historical Data
Purpose of Use	Focused on the provision of services	Focused on study and analysis
Processing Speed	Several seconds to tens of seconds	Several minutes to tens of minutes
Period for Saving	1-3 months	≥5yrs
Data Volume	Tens to hundreds of GBs	Tens to hundreds of TBs
Number of Transactions	Tens to hundreds of thousands of TPS	Tens to hundreds of TPS
Analysis Complication Level	$O(N^c)$	$O(e^n)$

Many matters should be considered in terms of technology when constructing the ADMS and some matters may be mentioned as the representatives. The first is the measures for the efficient integration of existing systems. The second is the efficient processing procedures and data quality maintenance measures for data integration. The third is the consideration of the technologies used to manage and analyze such integrated data and the application of the corresponding standards for data management. The fourth is the methodological guideline for the design of the entire systems based on technological considerations. Table 2 shows the classification and description of the matters to be considered in terms of technology when constructing the ADMS.

Table 2. Technological Considerations when Constructing the ADMS

Issues	Descriptions
System design guidelines	Some conceptual descriptions for the ADMS are provided in the national standards architecture but such descriptions do not satisfy the users' requirements in practical development. The developers should seek the optimum measures with which to construct the ADMS.
Whether or not there are requirements for the improvement of existing systems in order to construct the ADMS	The existing ITS may require functional improvement in order to construct the ADMS.
Quality of the data for analysis	The quality of the collected data for the planned ADMS is closely related with the performance of the ADMS.
Data standards	Establishment of the standards for ITS data. The requirements for the establishment of the measures to manage the meta data.

Data management techniques	The storage period and storage methods for the data should be established depending upon the kinds of rough and analyzed data.
Data analysis techniques	Which data analysis techniques should be applied depending upon the purpose of the analysis?
Integration of non-ITS data	How should the data, which is not directly used in the traffic management of the ITS and the provision of traffic information, be integrated?
Integration with other ITSs	How should the integration with other ITS systems be performed?
Reporting the analysis result	Measures for the automatic reporting of analysis results and the cycle for generating each report.

Source: ITS Data Archiving Five-Year Program Description

3. MAJOR FUNTIONS AND USE OF THE HISTORICAL DATA SYSTEM

(1) The major functions of the historical data system

The data currently collected by OASIS consists of VDS data, TCS data, Hi-pass data, CCTV video data, and meteorological data. The detector data should be processed and stored based on the processing and treatment studies that are currently being conducted to process the collected rough data in order to form highly credible and high-grade quality data. CCTV videos may be used in the video-related studies using the output equipment or video collection equipment in OASIS and the extracted images or videos may be used in the analysis in connection with the detector data after saving. The collected and stored data is analyzed using various analysis algorithms and data analysis techniques and, as not only the texts commonly used as the analysis results in other systems but also the graphs and GIS maps to improve the visual effect are produced, additional analyses that are impossible in the text-based analyses can be performed. The primary purpose of the historical expressway data management system is to improve the use of the collected detector data that is the basic data of the traffic management system, and to provide the foundation for the integration and analysis of TCS, Hi-pass, various kinds of historical data, and video information.

(2) Use of the historical data system

Using this system, it is possible to variously analyze the operational efficiency of the traffic management systems based on the long-term historical data and to easily perform the pre-treatment processing of the data in order to meet the purpose of collecting and studying traffic data. For example, in the case of the traffic operation analysis of detector data, cooperation from other departments was required in order to obtain the rough detector data, a process was required for processing the obtained rough data to meet the purposes of analyses, and a long time was taken in treating the large volume of data. The pre-treatment procedure for processing the detector data to meet the purposes of study

and analysis consists of ① Correction of abnormal values and missing data, ② Smoothing to relieve random fluctuations and noise, and ③ The process to convert to the aggregation unit to meet the purposes of the analyses. It is possible to conveniently and rapidly process the data in order to meet the purposes of studies by developing the integrated interfaces of the detector data that occupies the largest share in the analysis of the expressway traffic data.

Additional processes were required in the past to analyze the wide spatial range and the large volume of the traffic data of the expressway traffic management systems and to interpret the numerical results but such additional processes may be omitted if historical data is provided.

Also, it is possible to accomplish a visualization of the complicated analyses of the data escaping from simple numerical interpretation through visualization of the traffic data and the environment, which could not be perceived in the numerical analyses. This is provided through the intuitive interpretation of the analyzed results through the visualization of various kinds of analysis data.

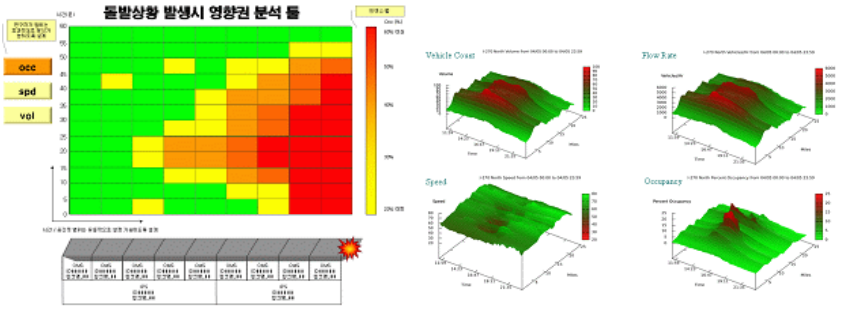

Figure 2. Example of the visualization of traffic data

3. THE DEVELOPMENT OF A HISTORICAL EXPRESSWAY DATA MANAGEMENT SYSTEM

(1) System Architecture

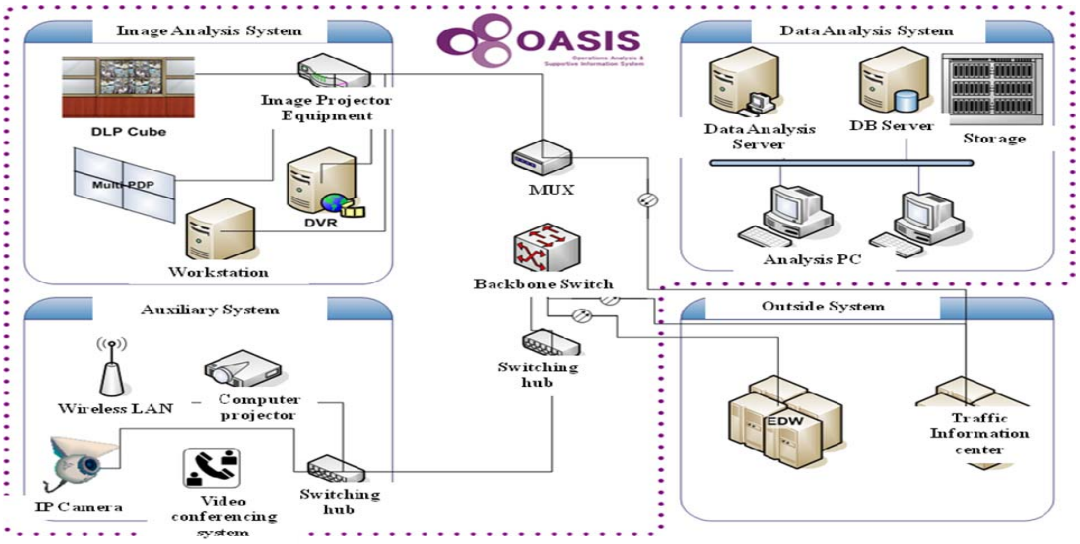

Figure 3. Structure of the entire system

Figure 3 shows the structure of OASIS to be constructed by Korea Expressway Corporation. As shown in the figure, OASIS is largely configured with a data analysis system, a video analysis system, and subsidiary facilities.

n the case of the video analysis system shown in Figure 3, the video received from the traffic information center through the optical link device is displayed on the DLP cube and multi-PDP and may be analyzed by the video analysis device. In addition, the historical traffic data received from the Operation system is saved in the DB server and the analytical studies are conducted by the analysis server. The software of OASIS consists of the DB management system for saving the historical expressway data and is designed in consideration of the processing of large-volume data rather than the number of transactions. Both the operation system and the DB management system are designed in consideration of outside systems to be connected with OASIS. In addition, statistical analysis tools, numerical interpretation tools, and web program tools for user services are available. When user services are provided on the web, the provided historical data and analysis environment may be used by anybody, anywhere. The hardware configuration of OASIS is designed in consideration of the volume of the data to be stored and the load on the analytical process and 40 TB of storage is provided to store large-volume traffic data for a long time and to avoid the disposal of historical data due to insufficient storage space. Currently, 40 TB of storage is expected to store the historical expressway data for about 5 years when the actual space of use rather than the physical space is considered. The storage may easily be expanded using a SAN (Storage Area Network) network. Exchange with outside researchers is easy when the video meeting system, which is installed as a subsidiary facility, is used and anybody can use the analytical data using the installed IP cameras.

(2) Web-based user interfaces

Figure 4 shows the structure of the hardware system which encompasses user interfaces to search the data stored in the OASIS based on the web.

Figure 4. Structure of the hardware system

Clients request services from the WebtoB web server, receive the result in HTML pages, and perform searches through their web browser. The users' requests are transmitted from WebtoB to the application programs of OASIS installed in the JEUS. The JEUS application program requests the needed data to the Oracle DB, processes the transmitted data, generates images, and transmits the images to WebtoB in HTML form.

Figure 5 shows the structure of the software.

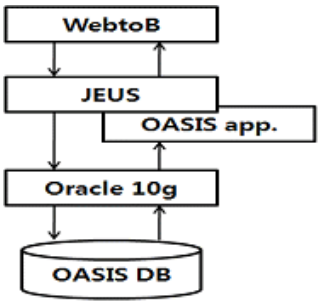

Figure 5. Structure of the software

Figure 6 shows the VDS data of expressways in the table after searching by driveway. The user sets the search conditions, i.e. the data set to be requested, and selects the aggregation unit. Aggregation units are available in 8 increments: 30 seconds, 1 minute, 5 minutes, 15 minutes, 1 hour, 1 day, 1 week, and 1 month.

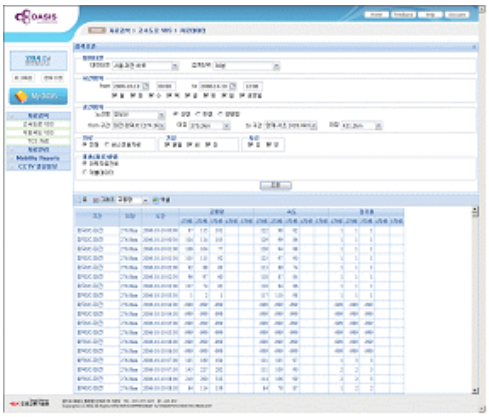

Figure 6. Search of data by the VDSs of expressways

It is possible to designate the range of dates as the range of time and to select a day of the week for searching. The starting point and ending point of the spatial range are selected based on the detectors on the expressways. Roadway data may be searched based on the whole roadways or bus roadways. It is also possible to search the meteorological status and the places where accidents have occurred.

Figure 7. Result of a search of speed graphs by the VDSs of expressways

Figure 7 shows the result of a search of speed graphs by the VDS of expressways The graphs show the speed, traffic volume, and occupation and each roadway is expressed in a different line. To receive and reprocess the result, the user may download the result in Excel files by clicking the Excel button.

4. CONCLUSIONS

The Intelligent Transport System is an integrated advanced solution for solving the traffic problems by maximizing the safety of road and traffic systems and the operational efficiency by grasping the technology of information communication, electricity and electronics, machinery, and control for the existing traffic. Researchers often suffer from large difficulties in extracting the intended data because real-time traffic data is stored in terms of given collection intervals and data type only, and because long-term data is not stored with any consideration of the measures for utilization when implementing ITS projects in the country. For the aforesaid requirements, examples of similar systems for storing and managing a large volume of historical traffic data were surveyed and analyzed and the matters for technological consideration for the efficient construction of the system were surveyed. OASIS is the basic system for storing and analyzing historical traffic data and has the purpose of providing traffic researchers with historical traffic data of good quality. For this, the DB server and analysis server were constructed in the system to process large-volume data and an environment was constructed for the traffic researchers to perform various analyses using historical traffic data. The CCTV video system in this system may be used to perform tasks related with CCTV video and it is possible to conduct complicated analytical studies, such as analytical studies compared with CCTV videos, based on the result of the analysis of historical traffic data. It is expected that such basic facilities and systems may be used for strengthening the capability of future traffic studies and for technological support and guidance in the corporation, and that they may be used as a part of traffic-related education and PR facilities to cultivate traffic researchers and to perform the role of PR.

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